Unit 4

Installation of Cables

Introduction

Electric power can be transmitted or distributed by two systems — overhead power line or underground cable system.

Power cables are used for power transmission and distribution purpose. It is an assembly of one or more individually insulated electrical conductors, usually held together with an overall sheath. It is used for transmission and distribution of electrical power. Electrical power cables may be installed as permanent wiring within buildings, buried in the ground and run overhead or exposed. Flexible power cables are used for portable devices, mobile tools and machinery. Power cables are defined by voltage grade and nominal cross sectional area.

Cables play a very important role in the distribution system. There are many types of cables like Low Tension (LT) cable, 11 kV cable and 33 kV cable. They are designed and manufactured as per voltage, current to be carried, maximum operating temperature and purpose of applications. For mining, extra mechanical strength is given to the cable with double armouring. For wind power plants, flexible and UV protected cables are required. The underground cables have several advantages, such as less liable to damage due to storms.

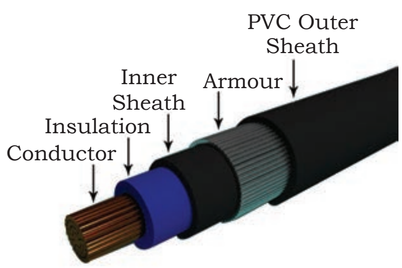

Fig.4.1 Parts of a cable

Cables are used in the places where bare conductor cannot be used due to narrow roads and are used in distribution transformer. LT cables are used for service line also.

Session 1: Laying of Underground Cables

An electrical cable (Figs. 4.1 and 4.2) is an assembly consisting of one or more conductors with their own insulations and screens, individual covering(s), assembly protection and protective covering.

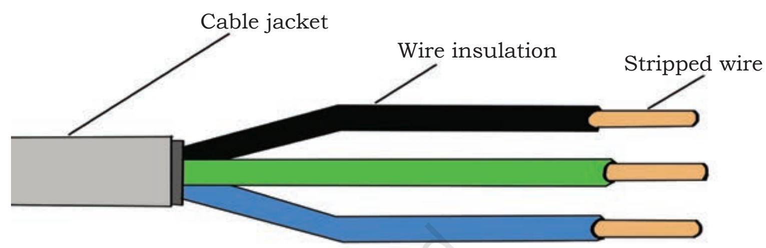

Fig. 4.2 Simple electric cable

Types of Cables

Cables are named according to the formation, voltage and material used. They are also named according to their use, that is, low tension or high tension cables, etc., as per voltage and single core, two cores, three cores, 3 1/2 core, etc.

Types of cables are classified in different ways on the basis of their uses, voltage and type of insulation used for their construction.

1. PVC (Polyvinyl Carbide Cable)
2. PILCA (Paper Insulated Lead Covered Armoured Cable)
3. XLPE (Cross-linked Poly Ethylene Cable)

Generally, PILC and XLPE cables are used in HT (High Tension) network, and oil or gas filled cables are used for EHV (Extra High Voltage) network. Proper cable end boxes shall be used for these cables. When the cable is not in use, both its ends should be properly sealed. PVC armoured cables are used for LT distribution (Figs. 4.3 and 4.4). A gland should be used at the cable end

to have earth continuity with armouring. It provides rigidity so that the cable does not swing and damage the insulation, and loose connection can be avoided. Apply M-seal to avoid water entry in the cable. While selecting the cable capacity, the safety factor must be taken into consideration. Conductors used in underground cables are made of aluminium and copper.

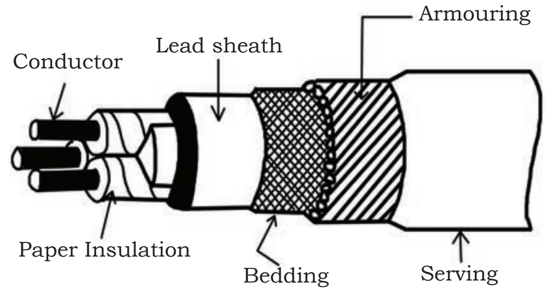

Fig. 4.3 Construction of cables

Generally XLPE (Cross-linked polyethylene) are used. The insulation of the cable must not deteriorate due to the high-voltage stress, ozone produced by electric discharges in air, or tracking. The cable system must prevent contact of the high-voltage conductor with other objects or persons, and must contain and control leakage current.


Fig. 4.4 Cross section of an HT cable

Cross-linked Polyethylene (XLPE insulation)

It is a form of polyethylene with cross-links. It is used predominantly in building services pipework systems, hydronic radiant heating and cooling systems, domestic water piping, and insulation for high tension (high voltage) electrical cables. Cross-linked Polyethylene, commonly abbreviated PEX, XPE or XLPE, is also used for natural gas and offshore oil applications, chemical transportation, and transportation of sewage and slurries (Fig. 4.5).

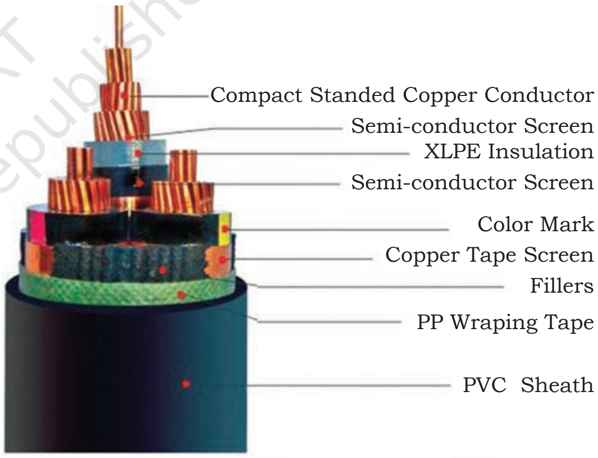

Fig. 4.5 XLPE cable

Paper Insulated Cable

These cables can be classified into two categories based on their construction.

- **Belted:** In a belted cable, the three cores are grouped together and then belted with the paper belt (Fig. 4.6). The gaps between the conductors and the paper insulation are filled with fibrous material, such as jute. This makes the cable to


Fig. 4.6 Belted cable

have a circular cross-sectional shape. The cores are not circular in shape. The cores are insulated from each other with impregnated paper.

Fig. 4.7 Screened cable

- **Screened:** It is an electrical cable of one or more insulated conductors enclosed by a common conductive layer. The shield may be composed of braided strands of copper (or other metal, such as aluminium), a non-braided spiral winding of copper tape, or a layer of conducting polymer (Fig. 4.7).

(a) Construction of belted/PILCA cables

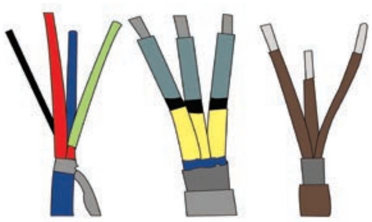

Fig. 4.8 PILCA cable

- **Conductor:** copper or aluminium, stranded, sector shaped
- **Insulation over core:** impregnated paper insulation wrapped over each conductor
- **Fillers**: placed in between the cores, made up of jute
- **Insulation over all cores:** belted paper insulation wrapped over all the cores
- **Lead sheath:** to protect the paper insulation from foreign elements and mechanical shock
- **Bedding:** to protect the lead sheath against corrosion. Consists of bitumen compound and impregnated cotton tapes
- **Armour:** provide mechanical strength to the cable, made of steel tape or round galvanised wire
- **Serving:** to protect the armour from corrosion, made of jute yarns coated with bitumen compound (Fig. 4.8).

(b) Disadvantages of PILCA

- Heavy due to lead sheathing
- Less flexible
- Poor resistance to vibration
- Difficulty in sealing and joining

High Tension Cables

A high-voltage cable (HV cable) is a cable used for electric power transmission at high voltage like 11kV, etc. This cable includes a conductor and insulation, and is suitable for being run underground or underwater.

XLPE Cable

XLPE cable means cross-linked polyethylene insulated aluminium conductor armoured cable (Fig. 4.9). In XLPE cable, stranded aluminium conductor is first screened in the form of a semi-conducting extrusion which provides a smooth conductor surface and prevents formation of cavities at the surface of the conductor when the cable is subjected to bending. The screened conductor is insulated with extruded XLPE compound. The insulation is further screened with layer of nonmetallic semiconducting material and over that a non-magnetic metallic screen in the form of copper or aluminium tape is applied. An important advantage of XLPE as insulation for medium and high voltage cables is their low dielectric loss. The dielectric loss factor is about one decimal power lower than that of paper insulated cables and about two decimal powers lower than that of PVC insulated cables. Since the dielectric constant is also more favourable, the mutual capacitance of XLPE cables is also lower, thus reducing the charging currents and earth-leakage currents in networks without the rigid star point earthing.

Fig. 4.9 XLPE cable

PVC Power Cable

Polyvinyl Chloride (PVC) insulated and sheathed cables are used in a wide variety of applications from fixed wiring to flexible installations, and are available in a number of sizes, colours and conductor materials (Fig. 4.10). As PVC is a thermoplastic polymer, PVC properties make it suitable for applications where the cables may be exposed to high or low temperatures (including use of arctic-grade PVC for extreme low conditions), or where protection against UV light is required to avoid degradation. PVC insulation is frequently used owing to its good insulating properties but low corona resistance, and is best suited for low and medium voltage cables and low frequency insulation requirements.

Fig. 4.10 LT PVC power cable

Junction Box

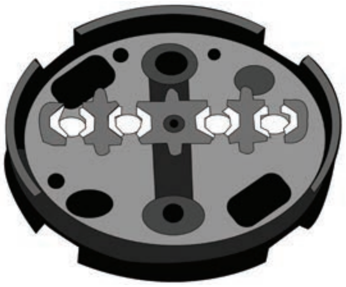

Fig. 4.11 Junction box

An electrical junction box is a container for electrical connections, usually intended to conceal them from sight and deter tampering (Fig. 4.11). A small metal or plastic junction box may form part of an electrical conduit or thermoplastic-sheathed cable (TPS) wiring system. During the laying of underground cables, junction box is used at the point where there is change in direction or another cable has to be laid in different direction.

Advantages of Underground Power Cable System

- Selection of route length is easy and simple
- Safety factor is very high
- Maintenance cost is almost negligible
- It has a good power factor
- It can be laid across zigzag and sharp bend routes with care

Disadvantages of Underground Power Cable System

- In case of any fault, it takes a lot of time to repair.
- Costly in comparison to overhead transmission system because of its initial cost and laying methods.
- Additional load cannot be taken up by the existing cables, hence necessitates the laying of new cables in case of load expansion.

Co-existing Underground Utilities

If the cable route comes across or is between co-existing underground utilities like sewer line, open drain, canal, bridge and other utility cable trench, the cable is protected by inserting it through a 6" GI pipe or as per the diameter of the cable throughout with mortar sealing at both side wall ends to give extra mechanical strength from damage due to exposure. If the cable route is along a bridge and we are unable to maintain the depth on foot path of bridge, then the cable is kept

covered with GI pipe duly clamped on side wall on footpath of the bridge.

Fig. 4.12 Exposed underground sewer pipe

In case canal or drain span is more than two metres, an additional MS channel rail is fabricated to lay the GI pipe covered cable route (Fig. 4.12). With rapid development of urban power networks, overhead line system face serious challenges in ensuring reliability of power supply, safety considerations, aesthetic appeal of the cities, for averting road and space congestion, etc. This places a special demand on underground cable network.

Cable Laying and Installation

Underground cables are, of course, meant to be installed or laid under the ground. The reliability of underground cable network highly depends upon proper laying of cables, quality of cable joints, branch connections, etc. There are a few points that need to be considered while laying and installing underground cables, which are

- selection of the route
- side of the street
- route with least obstacle should be preferred
- future load growth should be kept in mind

Methods of Cable Laying

There are various methods of cable lying, such as

- laying directly into the ground
- drawing in ducts
- laying on racks in air
- laying on rack inside a cable tunnel
- laying along building and structure

Underground Cables

HT cables can also be installed in the buried trenches. For this the cables are directly buried inside the ground (Fig. 4.13).

Fig. 4.13 Underground cables

Notes

Cable Trenches

Ladder type cable trays are erected inside the cable trenches and then the High Tension (HT) cables are laid on these cable trays (see Tables 4.1, 4.2 and 4.3). This is depicted in Fig. 4.14.

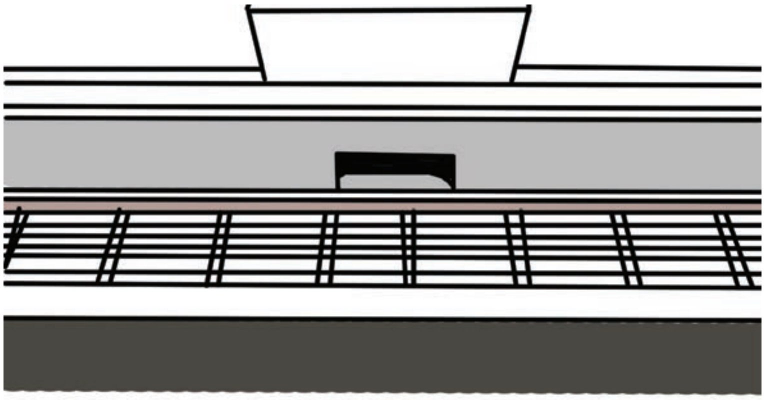

Fig. 4.14 Cable trenches

Cable Trench on the Open Pavement

A sand bed is prepared before the cable is laid over it (Fig. 4.15). Then the cable is covered with cement concrete duct or bricks to protect it from physical damage by pickaxe or hoe (Fig. 4.16). Afterwards, dressing is made with soil. MS route markers are placed at fixed points along the cable route.

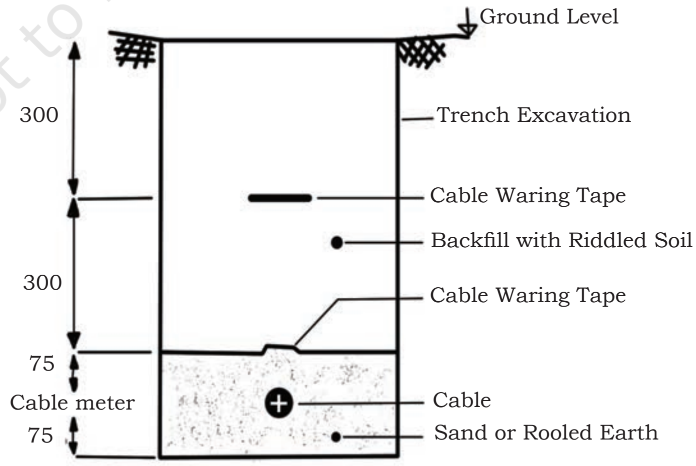

Fig. 4.15 Direct buried cables

Table 4.1 Minimum permissible Bending Radius

Voltage	PILCA	PILCA	PVC and XLPE	PVC and XLPE
	1 Core	3 Core	1 Core	3 Core
Up to 1.1 kV	20D	15D	15D	12D
1.1 to 11 kV	20D	15D	15D	15D
Above 11 kV	25D	20D	20D	15D

***D is diameter of cable**

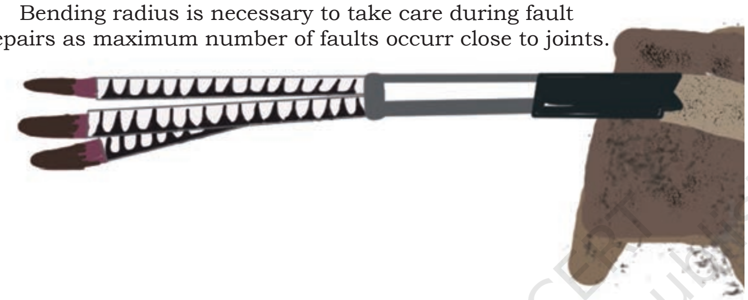

Fig. 4.16 Faults near joints

Table 4.2 Current Rating for HV cables

Cable Type	PILCA		XLPE	
Size of Cable in sq. mm	Rated Current in Amp	Derated Current in Amp	Rated Current in Amp	Derated Current in Amp
3 × 150	190	143	240	182
3 × 240	250	188	315	240
3 × 300	280	211	360	274
3 × 1000	585	445	685	550
3 × 300	290	215	352	264
3 × 400	332	249	402	301

Table 4.3 Current Rating for LT Cables

No. of Cores	Size in sq. mm	Rated Current	Derated Current
4	25	195	85
4	50	133	120
4	150	249	185
4	300	365	275

Fig 4.17 Cable drum with cable

Fig 4.18 Cable drum without cable

Derating Factors

- Cable depth
- Variation in ground and ambient temperature
- Thermal soil resistivity
- Spacing between cables
- Installation condition

While laying the cables necessary precautions and health and safety practices must be observed. 11 kV cable is laid from cable drums (Figs. 4.17 and 4.18) using erection tools and pulleys.

Other tools for cable laying are: Cable pulling winch, Cable guiding device, cable pulling grip, etc. While laying the cable, statutory clearances from the following authorities (managing co-existing underground utilities) may be obtained.

- Telephones
- Water Supply
- Drainage and Sewerage
- Railways
- Municipal Corporation
- National Highway
- Traffic (Police Department)
- Defence Authorities

Pulling Methods

The cable drum must be mounted on jacks and the cable rolled off the drum gently avoiding kinks and twists. The free end in the case of heavy cables may be pulled with the help of a winch. Laying of cable in open trench presents no serious difficulty. The cable is first placed on

rollers laid in the trench or on the ground above, which is then transferred to the bed of the trench. When laying cables in pipes and ducts, care should be exercised so as to not damage them during installation. The correct method of laying cable for installation in a duct is shown in Fig. 4.19.

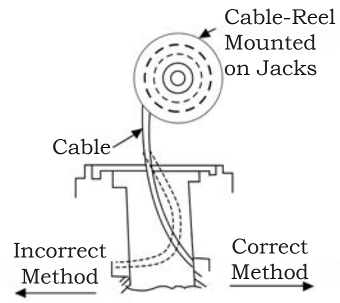

Fig. 4.19 Pulling methods

Underground Cable Testing

The cables are tested for the following faults:

1. Short Circuiting
2. Discontinuity
3. Earth fault

Murray Loop Test

For finding out the exact position of fault, cables are to be repaired without digging the whole cable route trench. For this purpose, the Murray loop test which is based upon the principle of wheat-stone bridge, and bridge megger is used. The Murray loop test is used for the location of faults on lines of low resistance, such as power cables and telephone cables. The circuit for Murray loop test is shown in Fig. 4.20 to locate the fault in a cable.

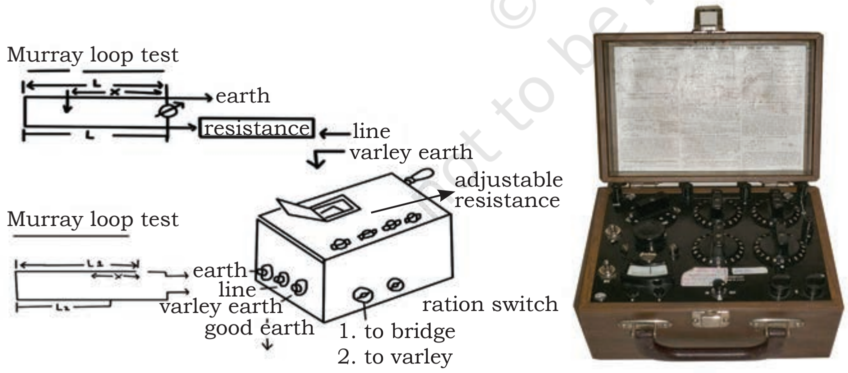

Fig. 4.20 Murray and Varley loop tests

The value of the resistance box (RB) and resistance dial of the instrument is changed till the galvanometer shows null point, that is, zero defection (handle of the meter is rotated at a speed of 160 r.p.m.). With this method we will be able to locate the distance of faulty section of the cable 'X' (as shown in Fig. 4.20).

NOTES

Connections

The conductors are shorted at its far end by a thick wire.

Precautions

1. For carrying out Murray loop test the only requirement is that all the core conductors should be of same cross-section.
2. If the sound and faulty conductors are of different sizes, it should be taken into account.

In high voltage cables, a high voltage DC is applied to the bridge network.

Varley Loop Test

This test is used to locate the fault of the long length cables; the connections are shown in Fig. 4.20 with the bridge mugger.

- The faulty line is joined at the far end to a good line by any link of negligible resistance.
- The faulty line is then joined to 'earth' terminal and the good line to the 'line' terminal. The 'Varley earth' terminal is connected to good earth.

The comparatively high resistance of the loop under these conditions allows a similar high resistance of R to be used. This means that the value of 'X' will not be greatly affected by small measuring inaccuracies.

Instructions

It will be seen that the only difference between the circuits is that the variable resistance R is used to obtain balance in the Varley Test, but it is omitted from the Murray Test (or say reduced to zero to be exact).

Check Your Progress

A. Fill in the blanks

1. _______________ test is used for the location of faults on lines of low resistance.
2. The current carrying capacity of 150 mm XLPE cable is _______________.
3. XLPE cables are used for _______________lines.
4. _______________are used to lay down the HV cables.

B. Write short notes on

1. Pulling method of cables
2. XLPE cable
3. Disadvantages of PILCA cable
4. Advantages and disadvantages of underground cable

C. Short answer questions

1. Classify various types of cables.
2. List the steps of cable laying.
3. List tools and equipment required for cable laying activities.

SESSION 2: LAYING OF AB CABLES

Aerial Bundled Cables

Aerial Bundled Cables (ABC) should not be confused with the bundle conductors used in high-voltage power transmission (Figs. 4.21 and 4.22). Aerial bundled cables are overhead power lines that use several insulated phase conductors bundled tightly together, usually with a bare neutral conductor. This contrasts with the traditional practice of using non-insulated conductors separated by air gaps.

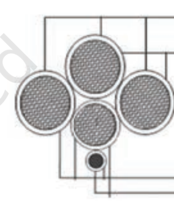

Fig. 4.21 Aerial bundled cable

Fig. 4.22 AL/XLPE insulated aerial bundled cables

The main objections to the traditional design are that the multiple conductors are considered external forces which can cause them to touch each other and cause a short circuit. The resultant sparks have been a cause of bushfires in drier climates. This is a potentially dangerous condition. With aerial bundled conductors (ABC), a simultaneous disconnection of all conductors is more likely to occur. In moister climates, tree growth is a significant problem for overhead power lines. Aerial bundled cables would not arc over, if touched by the tree branches. Although persistent rubbing is still a problem, tree trimming costs can be reduced. Areas with large trees and branches falling on lines are a problem for aerial bundled cables as the line degrades over time. Due to the very large strain forces, cracking and breaking insulation can lead to short circuit failures which can then lead to ground fires due to dripping of molten insulation.

Construction of insulated overhead power networks with ABC in developed industrialised countries today has almost completely superseded the traditional low-voltage network with bare conductors. Due to its advantageous technical, economic and aesthetical aspects, the low-voltage network type with aerial bundle conductors has found wide application.

Particular designs present a segment of standard product designs for suspension sets, tension sets and jointing equipment most commonly used in construction of low voltage (0.4kV) and medium voltage (10kV and 20kV) power lines with ABC accessories (Fig. 4.23).

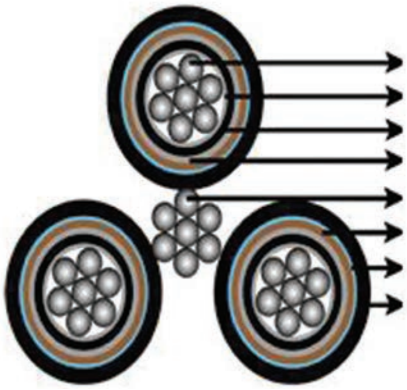

Fig. 4.23 MV aerial bundled conductor (ABC) cables

It is very difficult to tap the AB cables, thus reducing theft of electricity which leads to lower distribution losses.

Advantages of Aerial Bundled Cables

- Aerial bundled cables do not generate any spark when it touches the trees.
- Their appearance is good.
- They can be installed in narrow streets.
- Insulators and cross arms are not required.
- These cables are very safe as only neutral wire gets damaged in case of any accident.
- Electricity theft is merely possible.
- Short circuit is only possible when insulation of a cable is damaged.
- Insulating bridging wires are needed to connect non-insulated wires at either side at junction poles.

Disadvantages of Aerial Bundled Cables

- These cables are costly as compared to conductors.
- Insulation of cables get weaker due to heat of the sun.
- Due to the weight of the cables additional poles are required.

- It requires much longer time to repair the cable and also requires specialised equipment.
- Older installations can cause fires in areas where felling trees is common. Felling of trees may also cause breaks in lines and or insulation leading to short circuit.
- In areas with moderate climate, tree growth is signicant which causes a problem for overhead power lines.

Aerial bundled cables are suitable for these areas as they will not arc over if touched by tree branches. Although persistent rubbing can be a problem, however, tree-trimming costs can be reduced.

Types of AB Cables

AB Cables for LT Lines

AB cable consists of three phase wire, one neutral wire of lower size and a messenger wire. Configuration of AB cables varies from 95 mm^2 to 150 mm^2. These cables have current carrying capacity from 100 amp to 210 amp as per the load requirement. The messenger wire is used for earthing purpose. These heavy cables are used in LT line. Some time additional wire is also used for the purpose of lighting streetlight.

AB Cables for HT Lines (11kV)

In HT, 11 kV line AB cable consists of three phase wire, one messenger wire of lower size for earthing. AB cables do not have a neutral wire. Configuration of AB cable varies from 95 mm^2 to 150 mm^2.

Stringing and Jointing of Cables

(a) Stringing: The stringing of AB cable is easy through conventional methods but care shall be taken that cable insulation does not get damaged during installation. Dragging of cable on the ground can cause damage of insulation. Tension to be applied during stringing shall be 25% of the breaking load of the messenger wires. This will allow line to sag within the specified limit of 1.5% of the span at the lowest ambient temperature.

Notes

(b) Jointing: Mid-span jointing is permissible for LT ABC cable through conventional techniques. It is recommended to join the cable in such a way so as to bring the joints at the supports. Mid-span joining is not recommended in case of HT lines. Line tapping at the support may be allowed under unavoidable circumstances through suitably designed clamp connectors or parallel groove (PG) clamps. Tap off from power conductors in the area where catenaries are under tension is not recommended. The cable may be shorted and earthed through suitable non-liner surge arrestor (Figs. 4.24 and 4.25).

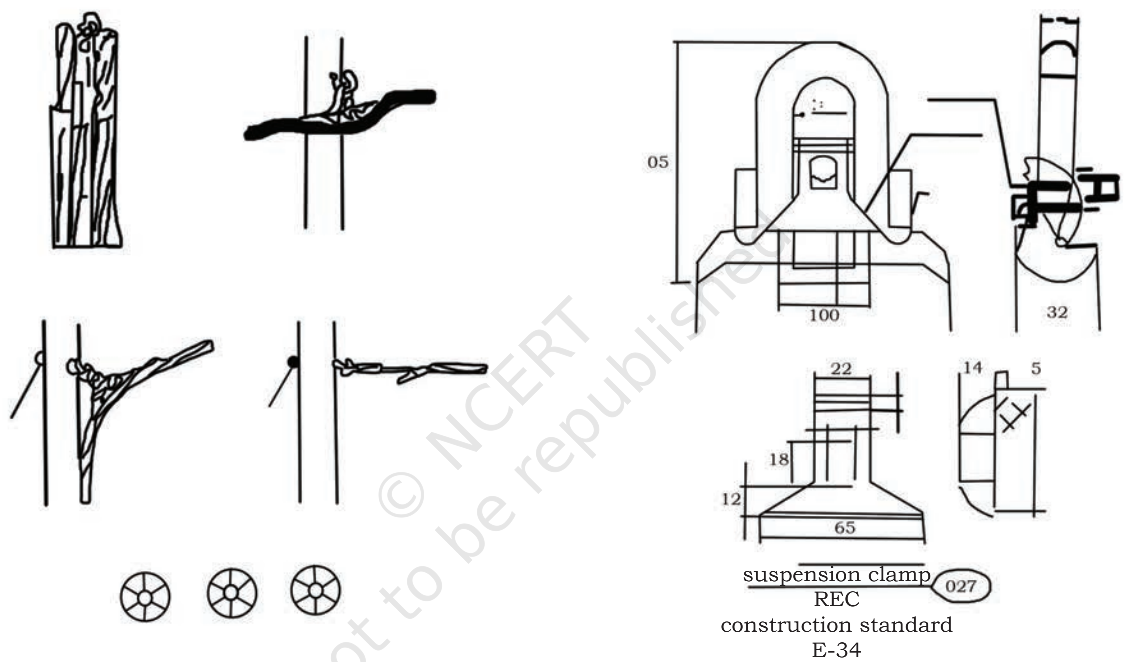

Fig. 4.24 ABC cable laying methods for different locations

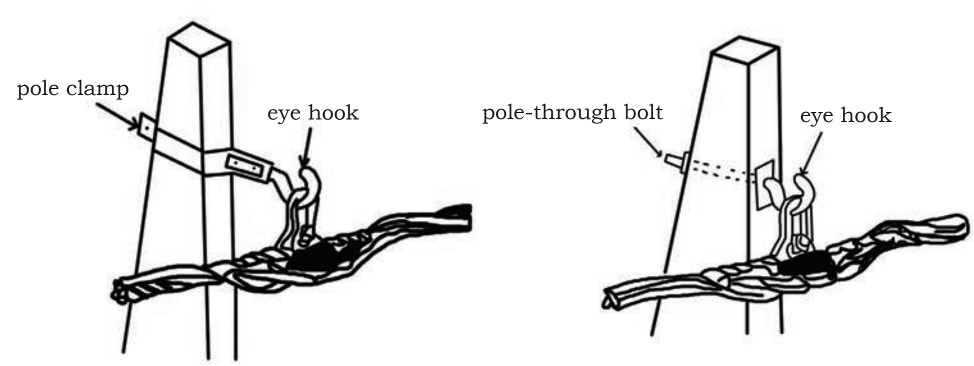

Fig. 4.25 Clamp for AB cable

Check Your Progress

A. Fill in the blanks

1. ______________ is used for branching of a service cable from a main cable.
2. Three faults that cables are tested for are ______________, discontinuity and earth fault.
3. ______________ are overhead power lines using several insulated phase conductors, contrasting with the traditional practice of using non-insulated conductors separated by air gaps.

B. State whether the following statements are True or False

1. Aerial Bundled cables are the same as bundle conductors
2. Mid-span jointing should be avoided in the case of HT lines
3. Laying the cables is important for power distribution. So, no clearances are required

C. Match the columns

Group A	Group B
1. A cable test	(a) Varley Loop Test
2. This test is used to locate the fault of the long length cables	(b) AB cables
3. Short spans, more poles needed	(c) Murray Loop Test

D. Short answer questions

1. Explain the importance of various cable joints.
2. List the advantages of Aerial bundled cables.

NOTES